Decision Support System for Determining Strategic Warehouse Locations Using a Combination of the WENSLO Weighting and RAWEC Method

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ABSTRACT

Determining the location of a strategic warehouse is a crucial decision in supply chain management as it directly affects distribution efficiency, logistics costs, and service levels. This problem is multi-criteria and complex, requiring an approach that can accommodate differences in the importance of criteria as well as variations in performance among alternatives objectively. This study aims to develop a Decision Support System to determine a strategic warehouse location by combining the Weights by Envelope and Slope (WENSLO) weighting method and the Ranking of Alternatives with Weights of Criterion (RAWEC) ranking method. The WENSLO method is used to generate criteria weights based on the nonlinear strength of each criterion, while the RAWEC method is applied to calculate the final values and determine the ranking of warehouse location alternatives. A case study was conducted on eleven alternative locations with the main criteria including location cost, accessibility, safety, distribution travel time, and proximity to suppliers. The study results showed that Trimurjo (TR) Location obtained the highest final score of 0.9673 and was designated as the top priority warehouse location, followed by Location Rumbia Daya (RD) with a score of 0.6235 and Harapan Ogan (HO) Location with a score of 0.338, while Candra Tunas (CT) Location had the lowest score of −0.975. These findings demonstrate that the combination of the WENSLO and RAWEC methods can produce rankings that are objective, consistent, and easy to interpret, making them a reliable decision-support tool for determining strategic warehouse locations and potentially applicable to other logistics and distribution problems.

Keywords: Decision support system, RAWEC, strategic warehouse location, supply chain management, WENSLO.

1. Introduction

The location of a warehouse plays a strategic role in improving the efficiency of the supply chain and logistics because it determines how effectively the flow of goods from suppliers to customers can be managed in terms of time, cost, and service reliability[1]–[3]. Proper warehouse placement can minimize distribution distances, reduce transportation costs, and speed up delivery times, thus directly impacting customer satisfaction and the company's competitiveness. In addition, a strategic warehouse location supports better coordination between production, storage, and distribution activities, especially in dealing with demand uncertainty and variations in shipment volumes. Factors such as access to transportation infrastructure, proximity to major markets and supply sources, as well as environmental conditions and regional regulations, also affect the operational effectiveness of warehouses in the long term[4], [5]. The decision on warehouse location becomes a key element in logistics planning, not only

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focused on cost reduction but also on enhancing flexibility, supply chain resilience, and the overall sustainability of logistics performance.

Determining a warehouse location faces various complex and interconnected challenges, particularly related to costs, accessibility, demand, infrastructure, and operational risks[6], [7]. From a cost perspective, companies need to balance land prices and operational expenses with the potential distribution efficiency gained. Accessibility is a challenge because the warehouse location must be connected to the main transportation network to ensure smooth and timely deliveries. Additionally, market demand uncertainty as well as limitations and the quality of logistics infrastructure make it difficult to determine the optimal warehouse location in the long term. In addition, risks such as natural disasters, congestion, regulatory changes, and security disruptions must be carefully considered as they can directly impact the continuity of distribution and the reliability of the supply chain[8]. Decision-making often involves many criteria with different levels of importance, which can potentially lead to subjectivity and inconsistency in the evaluation of determining the location of a strategic warehouse. Therefore, a systematic and objective approach is needed to assist decision-makers in determining the most strategic warehouse location based on various relevant criteria. The combination of these various factors makes warehouse location determination a strategic decision that requires thorough analysis and a systematic approach to ensure that the results are accurate, adaptive, and sustainable.

Decision Support Systems (DSS) based on multi-criteria decision making (MCDM) play an important role in helping decision-makers deal with complex problems that involve many interrelated and often conflicting criteria[9]–[12]. In a managerial and operational context, decisions are rarely determined by a single factor, but are influenced by economic, technical, risk, and performance aspects that must be evaluated simultaneously. The MCDM approach allows each criterion to be analyzed in a structured manner through weighting, normalization, and ranking of alternatives, resulting in decisions that are more rational and accountable[13], [14]. The existence of MCDM-based DSS also helps reduce subjectivity by transforming qualitative assessments into consistent quantitative values, as well as increasing transparency in the decision-making process[15]. With systematic data support and proven analytical methods, MCDM-based DSS becomes a strategic tool to improve decision accuracy, result consistency, and planning effectiveness in various fields, including logistics, human resources, and supply chain management.

The weights by envelope and slope (WENSLO) method is a weighting approach in multi-criteria decision making designed to determine the relative importance of each criterion in a systematic and structured manner based on preferences and data characteristics[16]–[18]. WENSLO works by evaluating the relationships between criteria through a consistent assessment process, so that the resulting weights can represent the actual influence of each criterion on the decision objective. The advantage of this method lies in its ability to reduce excessive subjectivity in weight assignment while maintaining a balance between conceptual assessment and the available numerical information. With more stable and rational weighting, WENSLO supports the process of evaluating alternatives more fairly and accurately, especially in decision-making problems involving multiple criteria with different levels of importance[19], [20]. The choice of the WENSLO weighting method is based on its ability to maintain assessment objectivity through modeling the nonlinearity of criteria strength, which is the condition where the influence of a criterion on a decision does not always increase linearly with changes in its value. Using WENSLO provides a more rational, stable, and objective basis for weighting, particularly in decision support systems that involve criteria with uneven levels of influence.

The ranking of alternatives with weights of criterion (RAWEC) method is a ranking method within the framework of MCDM used to determine the order of alternatives based on performance values and the weight of each criterion in an integrated manner[21]–[23]. RAWEC works by combining the evaluation scores of alternatives for each criterion with the predetermined criterion weights, resulting in an aggregate score that represents the overall preference level of each alternative. The advantage of this method lies in its simple yet consistent structure, making it easy to implement and transparent in explaining how the weights of criteria affect the ranking results. In addition, RAWEC is able to maintain the proportional contribution of criteria to alternatives, thereby reducing

result distortion when there are differences in the importance of the criteria[24]–[26]. With these characteristics, the RAWEC method is effectively used in DSS to generate alternative rankings that are rational, stable, and easy for decision-makers to interpret.

The combination of the WENSLO weighting and RAWEC methods offers a systematic and objective framework for determining strategic warehouse locations in complex logistics environments. WENSLO is used to derive criterion weights by capturing the nonlinear strength of each criterion, allowing the weighting process to reflect real differences in influence among factors such as cost, accessibility, demand coverage, infrastructure, and risk. This approach reduces subjective bias and produces stable, data driven weights. These weights are then integrated into the RAWEC method, which ranks alternative warehouse locations by aggregating their performance across all criteria in a clear and consistent manner. RAWEC ensures that each alternative is evaluated proportionally according to the importance of each criterion, resulting in a transparent and interpretable ranking. Through this combination, the decision support system is able to handle multi-criteria trade-offs effectively, improve ranking reliability, and support rational decision making in selecting warehouse locations that enhance supply chain efficiency and long-term logistics performance.

This study aims to develop a DSS for determining strategic warehouse locations by combining the WENSLO weighting method and the RAWEC ranking method. The combination of these two methods is intended to evaluate the ability of the method integration to produce objective criterion weights and consistent warehouse location rankings in complex multi-criteria problems. The contribution of this study lies in the application of the WENSLO and RAWEC integration as an analytical approach capable of capturing nonlinear differences in criterion strength in warehouse location determination. This study also provides a methodological reference for the development of DSS in logistics and supply chain fields with improved result objectivity and reliability.

The rest of the paper is organized as follows: Section 2 reviews various previous studies related to decision support systems for determining strategic warehouse locations, serving as the theoretical and empirical foundation of the research. Next, Section 3 provides a detailed explanation of the proposed method, which is the integration of WENSLO and RAWEC, including the basic concepts and implementation stages. In Section 4, the results of experiments obtained from case studies are presented, along with analysis and discussion to evaluate the performance of the proposed method. Finally, Section 5 presents the research conclusions, summarizing the main findings and providing directions for future research development.

2. Literature Review

DSS for determining strategic warehouse locations has become a critical research area due to the growing complexity of logistics networks, increasing distribution costs, and the demand for faster and more reliable service levels. The literature review in this domain serves to examine existing models, decision frameworks, and analytical methods applied to warehouse location selection, particularly those based on multi-criteria decision making that integrate economic, operational, spatial, and risk-related factors. By systematically reviewing prior studies, this section highlights how different weighting and ranking approaches address trade-offs among conflicting criteria, while also revealing persistent challenges such as subjectivity in criteria importance, sensitivity to data variation, and limited adaptability to heterogeneous logistics environments. This review therefore provides a structured theoretical and empirical foundation for developing a more robust and objective DSS framework tailored to strategic warehouse decision making.

The research conducted by Wahyudi [27] applied the TOPSIS method combined with PIPRECIA weighting to determine strategic locations for a new warehouse by considering criteria such as distance to the factory, area size, and distribution access. The findings of this study illustrate the effectiveness of integrating TOPSIS and PIPRECIA in providing data-driven decision recommendations for more efficient logistics planning[27]. Unlike the study [27] that combined TOPSIS with PIPRECIA and still relied on expert preference assessments in determining the criteria weights, this study proposes the use of WENSLO as a weighting method that is entirely data-driven (objective weighting). This approach allows the criteria weights to be determined automatically based on the characteristics

of the data distribution, thereby reducing subjectivity and improving the stability of results when there are changes in data or logistics environment conditions. The research conducted by Hassaballa [28] developed an algorithmic approach based on the Complex Pythagorean Fuzzy Soft Set (CPFSS) for warehouse location selection in the context of supply chain management, aiming to address the uncertainty and ambiguity of data that often arise in site selection evaluation. The findings indicate that integrating CPFSS with distance measures provides a robust framework for supporting strategic warehouse location decisions while considering complex data variations[28]. The difference from the study [28] lies in relying on the Complex Pythagorean Fuzzy Soft Set (CPFSS) approach to handle uncertainty and ambiguity in data for warehouse location determination. Although theoretically robust, this fuzzy approach has mathematical complexity and high computational demands, which can limit its applicability in operational contexts. In contrast, this study uses RAWEC as a ranking method that is computationally simpler, yet still capable of effectively capturing relationships between criteria and alternatives, making it more adaptable for practical implementation.

Research by Isyriyah [29] developed a DSS to assist in selecting culinary business locations by combining the Analytic Hierarchy Process (AHP) method to determine criteria weights and TOPSIS to evaluate alternative locations based on their proximity to the ideal solution. The integration of the DSS with a map API also adds practical functionality to help decision-makers in visualizing and assessing locations spatially, thereby supporting more informative and contextual decisions[29]. Research by Rianingsih [30] developed an Android-based DSS that uses the AHP method to assist entrepreneurs in selecting the optimal business location by evaluating several important criteria such as accessibility, cost, demographics, competition, security, infrastructure, regulations, and growth potential. This system is designed to improve accuracy and efficiency in the business location selection process, especially for decision-makers who need quick access in the field and transparency of criteria weights in the evaluation[30]. The difference from the research by [29] and [30] lies in emphasizing the development of a DSS based on AHP and TOPSIS as well as implementational aspects such as the integration of digital maps and mobile platforms. Although they add value in terms of visualization and ease of use, these approaches are still highly dependent on subjective weighting of criteria and place less emphasis on analyzing the stability of decision outcomes. This study differs because it focuses more on methodological robustness through the combination of WENSLO–RAWEC, so that the DSS developed is not only easy to use but also produces more consistent and transparent recommendations.

Based on the results of the literature review, there are still research gaps in the development of DSS for determining strategic locations, particularly warehouses, that have not been fully addressed. Various studies indicate that integrating weighting and ranking methods based on MCDM can produce more systematic and structured decision recommendations; however, most of these approaches still rely on subjective assessments in determining criterion weights, which can potentially lead to result instability when preferences or data conditions change. Fuzzy-based approaches have been introduced to handle data uncertainty and ambiguity, but the mathematical complexity and high computational requirements often limit their application in practical and operational contexts. On the other hand, the development of DSS that focuses on implementation aspects, such as mobile-based systems and digital map integration, emphasizes ease of use rather than the robustness of methods in dealing with heterogeneous and dynamic multi-criteria data. In addition, comparative studies of alternative methods as well as sensitivity analyses of weights and data are still relatively limited. Therefore, further research is needed to propose a DSS approach for warehouse location determination that is more objective, stable, and adaptive, while still maintaining ease of implementation for decision-makers in a complex logistics environment.

The main contribution of this research lies in the integration of the objective weighting method WENSLO and the RAWEC ranking method in DSS for determining strategic warehouse locations. This approach is capable of addressing gaps in previous research by providing a more objective solution, stable against data changes, adaptive to heterogeneous multi-criteria characteristics, and still practical to implement in a dynamic and complex logistics environment.

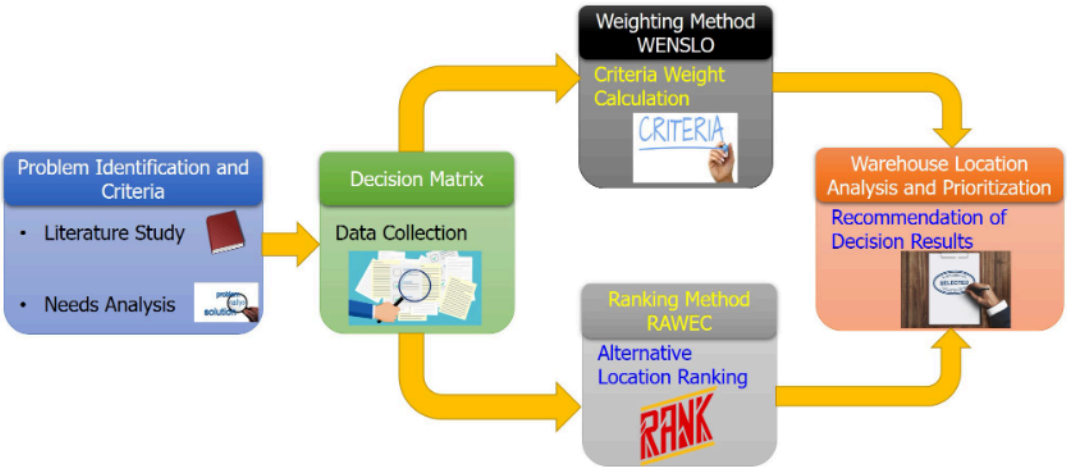

Fig. 1: Research design.

3. Methodology

The research methodology is designed to provide a systematic and measurable framework for achieving research objectives and addressing the formulated problems[31], [32]. This section explains the research stages in a sequential manner, starting from problem identification and criteria determination, data collection and processing, to the application of methods used in the Decision Support System. The chosen methodological approach is designed to ensure that the decision-making process is carried out objectively, consistently, and replicably, particularly in handling heterogeneous multi-criteria data. With a clear and structured methodology, the research results are expected to have a strong analytical foundation and be relevant to supporting strategic decision-making.

3.1. Research Design

This research design is developed using a quantitative approach with an MCDM-based DSS framework to determine strategic warehouse locations. The study begins with problem identification and the establishment of relevant criteria through literature review and logistics needs analysis. Next, data on location alternatives are collected and organized into a decision matrix as the basis for analysis. The criteria weights are calculated using the WENSLO method to objectively represent the relative strength of each criterion, and these weights are then integrated into the RAWEC method to rank the warehouse location alternatives. The final results, in the form of a prioritized sequence of locations, are analyzed to assess the consistency and rationality of the decisions, ensuring that this research design guarantees a systematic, measurable, and accountable decision-making process. Fig. 1 illustrates the research design developed in the study.

The diagram illustrates the workflow of a decision support system in determining strategic warehouse locations using a combination of the WENSLO weighting method and the RAWEC ranking method. The process begins with problem identification and criteria determination through literature study and needs analysis, followed by data collection to form a decision matrix. Then, the matrix is used in the WENSLO method to calculate the weight of each criterion objectively. The resulting weights then serve as the basis for the alternative location ranking stage using the RAWEC method to determine the priority order of the best locations. The final result of this process is a recommendation for the most optimal warehouse location based on the analysis and ranking conducted.

3.2. The Weights by Envelope and Slope (WENSLO) Method

The weights by envelope and slope (WENSLO) method is an objective weighting approach in multi-criteria decision making that is designed to determine the relative importance of criteria based on the strength and pattern of their data distribution[33]. WENSLO evaluates how changes in criterion values influence the decision outcome by considering the envelope and slope characteristics of each criterion, allowing it to capture nonlinear relationships among criteria more effectively than linear weighting methods. Through this mechanism, criteria with stronger and more sensitive impacts on alternative performance receive higher weights, while criteria with weaker influence are assigned lower importance. This approach reduces dependence on subjective judgments and improves the stability

of the weighting results, especially in decision problems involving heterogeneous and conflicting criteria. As a result, the WENSLO method provides a rational and data driven foundation for weighting criteria in decision support systems that require high objectivity and consistency.

The WENSLO method is implemented through several systematic stages to ensure objective and consistent weighting of criteria. First, the decision matrix is constructed by compiling the performance values of all alternatives across each criterion, which serves as the primary input for analysis. At this stage, the data reflect the real characteristics of each criterion and allow differences in scale and distribution to be observed clearly. A well-structured decision matrix is essential because it directly affects the accuracy of subsequent weighting results.

$$X = [x_{ij}]_{mxn} \tag{1}$$

The decision matrix represents the initial data set in a multi-criteria decision-making problem, where each element x_{ij} indicates the performance value of the i^{th} alternative with respect to the j^{th} criterion. This matrix is composed of m alternatives being evaluated and n assessment criteria used as the basis for evaluation.

Second, data normalization is performed to transform the criterion values into comparable scales without altering their relative patterns. This step ensures that criteria with larger numerical ranges do not dominate those with smaller ranges. Normalization also preserves the inherent distribution shape of each criterion, which is important for identifying nonlinear strength.

$$z_{ij} = \frac{x_{ij}}{\sum_{i=1}^{m} x_{ij}} \tag{2}$$

The symbol z_i represents the normalized value for the i^{th} alternative on the j^{th} criterion, which has been scaled proportionally. The symbol x_i indicates the initial value or performance value of the i^{th} alternative with respect to the j^{th} criterion found in the decision matrix. The notation $\sum_{i=1}^{m} x_i$ denotes the summation of all x_i values from the first to the m-th alternative for the same criterion, which functions as the divisor in the normalization process.

Third, the calculation of class intervals is carried out to group criteria based on the level of influence strength in a systematic and objective manner. The difference between the maximum and minimum values is then calculated to determine the data range that represents the variation in the strength of all criteria.

$$\Delta Z_j = \frac{max_j\, z_{ij} - min_j\, z_{ij}}{1 + 3.322 * log(m)} \tag{3}$$

The symbol ΔZ represents the class range or data interval value for the j^{th} criterion used in the process of grouping or analyzing the distribution of normalized values. The symbol z_i is the normalized value of the i^{th} alternative with respect to the j^{th} criterion. The notation max z_i indicates the maximum value of all normalized values z_i for the j^{th} criterion, while min z_i indicates the minimum value for the same criterion. The difference between the maximum and minimum values represents the distribution of normalized data for that criterion. The symbol m denotes the total number of alternatives evaluated, while the function log(m) is the logarithm of the number of alternatives used to statistically determine the number of classes. The constant 3.322 refers to Sturges' rule, commonly used in data analysis to determine the optimal number of intervals.

Fourth, slope analysis is conducted to measure the rate of change within each criterion based on its envelope characteristics. This stage captures the nonlinear strength of criteria by identifying how sensitive the decision outcome is to variations in criterion values. Higher slope values indicate criteria that exert greater influence on the ranking of alternatives.

$$\varphi_j = \frac{\sum_{i=1}^{m} z_{ij}}{(m-1) * \Delta Z_j} \tag{4}$$

The symbol φ represents the parameter value or measurement index for the j[th] criterion, reflecting the degree of dispersion or intensity of variation in the normalized values of that criterion. The symbol z_i denotes the normalized value of the i[th] alternative with respect to the j[th] criterion, while the notation $\sum_{i=1}^{m} z_i$ indicates the total normalized value of all alternatives for the same criterion. The symbol m represents the number of alternatives being evaluated, so the factor (m − 1) is used as an adjustment for the number of intervals or degrees of freedom in the calculation. The symbol ΔZ is the class interval width for the j[th] criterion, which was previously calculated based on the spread of normalized values.

Fifth, the envelope value of each criterion is determined to represent the upper and lower bounds of its normalized data. These envelope values describe the spread and intensity of criterion performance across all alternatives. Criteria with wider and more informative envelopes indicate stronger discriminatory power in the decision-making process.

$$E_j = \sum_{i=1}^{m-1} \sqrt{\left(z_{i+1j} - z_{ij}\right)^2 + \Delta Z_j^2} \tag{5}$$

The symbol E represents the total distance value or the energy measure of dispersion for the j[th] criterion used to represent the level of variation between normalization values sequentially. The symbols z_i and z_{i+1}, respectively indicate the normalized values of the i[th] alternative and the (i+1)[th] alternative for the j[th] criterion, reflecting the change in value between adjacent alternatives. The squared difference $(z_{i+1} - z_i)^2$ represents the vertical distance between two normalization points, while $(\Delta Z)^2$ represents the fixed horizontal distance derived from the interval width of the j[th] criterion. The square root operator represents the Euclidean distance calculation between two consecutive points in a two-dimensional space. The index i = 1 to m − 1 indicates that the calculation is performed for all consecutive alternative pairs, while m represents the total number of alternatives.

Sixth, the value of the proportion of the criterion envelope is calculated to measure the relative strength of each criterion based on the spread of its normalized data. This calculation compares the envelope value of a criterion with the total envelope values of all criteria, ensuring proportional representation. Through this process, criteria with wider and more informative data distributions obtain higher proportional values.

$$q_j = \frac{E_j}{\varphi_j} \tag{6}$$

The symbol q represents the final index value for the j[th] criterion, reflecting the relative importance level or objective weight of the criterion based on the characteristics of its data distribution. The symbol E is the total distance value or the accumulated variation of normalized values for the j[th] criterion, obtained from sequential calculations of distances between alternatives. The symbol φ is a normalization parameter for the j[th] criterion that serves as a balancing factor to control the influence of the number of alternatives and the data interval width.

Finally, the criterion weights are calculated and normalized by integrating the envelope and slope results into a single weighting value. This produces a set of objective weights whose total equals one and reflects the relative importance of each criterion. The final weights can then be directly applied in ranking methods to generate consistent and reliable decision outcomes.

$$w_j = \frac{q_j}{\sum_{j=1}^{n} q_j} \tag{7}$$

The symbol w represents the final weight of the j[th] criterion that has been normalized so it can be directly used in the evaluation and ranking of alternatives. The symbol q is the objective importance index value of the j[th] criterion obtained from the previous calculation stage and reflects the level of information variation in that criterion. The notation $\sum_{=1}^{n} q$ indicates the sum of all q values from the first criterion to the n[th] criterion, serving as a divisor factor so that the total weight equals one.

The weight results obtained from the WENSLO method show differences in the level of importance among the criteria, which are formed objectively based on the strength and variation of the data. These weights represent the actual contribution of each criterion in influencing the decision-making process. By taking into account the nonlinear characteristics of the criteria's strength, WENSLO weights are more stable and rational. Therefore, the resulting weights can be reliably used as a basis for ranking alternatives in the subsequent analysis stage.

3.3. The Ranking of Alternatives with Weights of Criterion (RAWEC) Method

The ranking of alternatives with weights of criterion (RAWEC) method is used as a systematic approach to determine the priority order of alternatives by integrating the performance values of alternatives and the weights of each criterion[34], [35]. This method focuses on combining weighted multi-criteria evaluations into a clear and consistent preference value. By directly incorporating the criterion weights into the calculation process, RAWEC ensures that the importance level of each criterion is proportionally reflected in the final results. Therefore, the RAWEC method provides a transparent and reliable ranking mechanism to support decision-making in complex multi-criteria problems.

The initial stage of the RAWEC method begins with preparing a decision matrix that contains all the alternatives and criteria used in the evaluation. Each element of the matrix represents the performance value of an alternative against a specific criterion. This matrix serves as the main basis for the subsequent calculation process using (1).

The second stage of the RAWEC method is normalization, which is carried out to convert the values in the decision matrix into a comparable scale so they can be fairly compared. This process prevents criteria with a large value range from dominating other criteria. Normalization also ensures that the performance pattern of the alternatives is maintained without altering its original proportion, calculated using (8) for benefit criteria and (9) for cost criteria.

$$n_{ij} = \frac{x_{ij}}{max_j\, x_{ij}}, and\ n_{(ij)'} = \frac{min_j\, x_{ij}}{x_{ij}} \tag{8}$$

$$n_{ij} = \frac{min_j\, x_{ij}}{x_{ij}}, and\ n_{(ij)'} = \frac{x_{ij}}{max_j\, x_{ij}} \tag{9}$$

The symbol n_i represents the normalized value for the i^{th} alternative on the j^{th} criterion that is a benefit, where a higher value indicates better performance. The symbol n_i' represents the normalized value for a criterion that is a cost, where a lower value is considered more optimal. The symbol x_i is the initial value or performance value of the i^{th} alternative on the j^{th} criterion in the decision matrix. The notation max (x_i) indicates the maximum value among all alternatives for the j^{th} criterion, while min (x_i) indicates the minimum value for the same criterion. The index I represents alternatives and j represents criteria.

The third stage of the RAWEC method calculates the normalized result values combined with the criteria weights to determine the deviation level of each alternative. This deviation indicates the extent to which the performance of the alternative aligns with the importance level of the criteria. The smaller the deviation produced, the better the alternative in meeting the weighted criteria using (10) and (11).

$$v_i = \sum_{i=1}^{m} w_j * (1 - n_{ij}) \tag{10}$$

$$v_{i'} = \sum_{i=1}^{m} w_j * (1 - n_{(ij)'}) \tag{11}$$

The symbol v_i represents the preference value or evaluation score of the i^{th} alternative for a benefit-type criterion, whereas v_i' represents the preference value of the i^{th} alternative for a cost-type criterion. The symbol w denotes the weight of the j^{th} criterion, reflecting the relative importance of each criterion in the decision-making

process. The symbol n_i is the normalized value of the i^{th} alternative for the j^{th} criterion for a benefit criterion, while n_i' is the normalized value for a cost criterion. The expressions $(1 - n_i)$ and $(1 - n_i')$ are used to measure the degree of deviation or distance of the alternative from the ideal condition. The summation operator $\sum_{=1}^{n}$ indicates that the calculation is carried out by accumulating the contributions of all criteria from the first to the n^{th} criterion.

The final stage of the RAWEC method is to calculate the final value by accumulating all the deviations obtained for each criterion. This value is used as the basis for determining the overall ranking of alternatives, calculated using (12).

$$Q_i = \frac{v_{i'} - v_i}{v_{i'} + v_i} \tag{12}$$

The symbol Q_i represents the balance index value or preference ratio for the i^{th} alternative used as the basis for the final ranking. The symbol v_i represents the preference value of the i^{th} alternative obtained from the aggregation of benefit-type criteria, while v_i' represents the preference value of the i^{th} alternative derived from the aggregation of cost-type criteria. The difference $(v_i' - v_i)$ illustrates the relative comparison between the contribution of cost and benefit aspects for that alternative, whereas the sum $(v_i' + v_i)$ serves as a normalization factor to keep the index value within a controlled range.

The RAWEC method provides a clear and consistent ranking framework by proportionally integrating the performance of alternatives and the weights of criteria. This approach is capable of displaying the quality differences between alternatives in a rational manner through calculations that are easy to understand and transparent. The RAWEC method is suitable to be used as an effective decision support tool in multi-criteria problems, especially in the context of determining strategic warehouse locations.

4. Result and Discussion

A decision support system for determining strategic warehouse locations using a combination of the WENSLO weighting and RAWEC method has been developed to address the complexity of decision-making in logistics planning, which involves multiple criteria with varying levels of importance. Determining warehouse locations does not solely depend on cost factors but is also influenced by transportation accessibility, proximity to markets and suppliers, infrastructure conditions, and operational risks that can affect overall supply chain performance. This complexity requires an approach capable of processing multi-criteria data in an objective, systematic, and consistent manner so that the decisions made can be accountable. A decision support system based on multi-criteria decision making is a relevant solution because it can integrate various quantitative and qualitative factors within a single analytical framework. In this context, the WENSLO method is used to generate criterion weights objectively by considering the nonlinear strength of each criterion, while the RAWEC method plays a role in ranking warehouse location alternatives proportionally based on those weights. The combination of these two methods is expected to produce more accurate, stable warehouse location recommendations and support improvements in logistics efficiency and supply chain competitiveness in the long term.

4.1. Problem Identification and Criteria

Identifying the problem in determining the location of strategic warehouses arises from the high complexity of decisions that must consider various interrelated and often conflicting criteria. Companies face demands to reduce distribution costs while increasing the speed and reliability of services, while geographical conditions, infrastructure, and market demand continue to change. In practice, warehouse location decisions are still often based on experience, intuition, or single considerations such as land costs, thus neglecting other equally important factors. This approach has the potential to result in suboptimal decisions, leading to increased operational costs, inefficiencies in the flow of goods, and a decline in overall supply chain performance. In addition, problems also arise from the limitations of conventional methods in processing heterogeneous multi-criteria data that have uneven levels of influence. Many weighting and ranking methods still assume linear relationships between criteria, making them less capable of representing the true strength of each factor in real conditions. This inability can cause criterion weights to become biased and the ranking results of alternatives to become unstable when data changes occur.

Table 1: Criteria for determining strategic warehouse locations.

Criteria Code	Criteria Name	Type	Description
WL-1	Location Cost	Cost	Describes the total costs arising from choosing a warehouse location, including land prices, rental or construction costs, taxes, and long-term operational expenses. This criterion directly affects logistics cost efficiency.
WL-2	Accessibility	Benefit	Shows the ease of the warehouse location in accessing major transportation networks such as highways, ports, or distribution centers. Good accessibility supports smooth distribution and timely deliveries.
WL-3	Location Security	Benefit	Indicates the level of security in the warehouse area from the risks of theft, vandalism, and social disturbances. Good security enhances asset protection and operational smoothness.
WL-4	Distribution Travel Time	Cost	Represents the average time required to distribute goods from the warehouse to the destination area. Shorter travel times improve service responsiveness.
WL-5	Proximity to Suppliers	Cost	Represents the distance and ease of access of the warehouse to main supply sources. A location close to suppliers can reduce lead time and inbound logistics costs.

Therefore, a Decision Support System is needed that can identify and model the warehouse location determination problem more objectively and systematically, taking into account the nonlinear characteristics of the criteria and producing consistent and reliable location rankings.

Identifying criteria is an important step in determining a strategic warehouse location because it serves as a basis for evaluating and comparing each location alternative objectively. The selected criteria must be able to represent the main factors that influence logistics efficiency and performance, both operationally and strategically. In this context, the criteria generally include cost aspects such as land price and operational expenses, accessibility related to proximity to major transportation networks, and the level of market demand that the warehouse must serve. In addition, infrastructure criteria, reflecting road quality, supporting logistics facilities, and availability of utilities, also need to be considered as they directly affect the smoothness of distribution activities. In addition to these main factors, the identification of criteria must also include risk and sustainability aspects to ensure that warehouse location decisions remain relevant in the long term. The risks referred to include potential natural disasters, traffic congestion, regulatory changes, and security disruptions that could hinder logistics operations. The process of identifying criteria is carried out through literature studies, organizational needs analysis, and discussions with relevant parties to ensure that the criteria used are comprehensive and contextual. With clearly defined and measurable criteria, the Decision Support System can process information more accurately, so that the evaluation and ranking results of warehouse locations reflect real conditions and support rational and accountable decision-making. Table 1 is the criteria in determining strategic warehouse locations.

Problem identification and criteria are the main foundation in determining a strategic warehouse location because they guide the direction and quality of the entire decision-making process. A clear problem formulation allows for a comprehensive understanding of the logistics complexities encountered, while proper identification of criteria ensures that every important factor is evaluated proportionately and measurably. By integrating various aspects such as cost, accessibility, and other supporting factors, the decisions made become more comprehensive and relevant to real conditions.

4.2. Data Collection

Data collection is a crucial stage in research for determining strategic warehouse locations because the quality of the data used greatly determines the accuracy of the analysis results and decision recommendations. At this stage, data is collected to represent the real conditions of each location alternative based on established criteria. Data sources can come from primary data, such as field surveys, interviews with management and logistics practitioners, as well as direct observation of the site conditions. In addition, secondary data is also used, including company reports, government statistical data, transportation maps, and relevant regional planning documents. The combination of primary and secondary data allows for the preparation of a more comprehensive and objective decision

Table 2: Data collection.

Alternative Location	Criteria Code				
	WL-1	WL-2	WL-3	WL-4	WL-5
Abung Selatan (AS) Location	420	82	80	38	18
Eka Dharma (ED) Location	450	88	83	41	22
Rumbia Daya (RD) Location	390	76	78	35	12
Yosomulyo Asri (YA) Location	480	85	88	46	30
Trimurjo (TR) Location	360	70	72	37	10
Fajar Timur (FT) Location	440	80	85	40	25
Gunung Qori (GQ) Location	400	78	77	39	20
Candra Tunas (CT) Location	495	90	89	50	45
Harapan Ogan (HO) Location	370	74	73	36	15
Gunung Katun (GK) Location	455	84	81	42	28
Tulang Bawang Udik (TU) Location	410	79	76	38	18

matrix. In addition to paying attention to data sources, the data collection process also emphasizes consistency, accuracy, and the suitability of data for multi-criteria analysis needs. The data obtained must be adjusted to the appropriate measurement scale so that it can be processed quantitatively in a DSS.

The collection of assessment data is carried out to provide performance scores for each warehouse location alternative based on criteria that have been systematically and measurably established. This assessment data is obtained through a combination of quantitative measurements, such as distance, cost, and travel time, as well as qualitative evaluations that are converted into numerical scales so that they can be processed in a DSS. The assessment process involves parties who understand the logistics and operational context to ensure that the scores given reflect the real conditions in the field. In addition, the alignment of scales and consistency in assessment are key concerns to prevent distortion between criteria. With accurate and consistent assessment data, the resulting decision matrix is able to objectively represent the performance differences of alternatives and support a reliable weighting and ranking process. Table 2 shows the results of the assessment data collection conducted in this study.

The collection of assessment data becomes a crucial stage that determines the quality of the decision matrix in selecting strategic warehouse locations. Assessment data that is systematically and consistently compiled allows each alternative to be evaluated fairly based on the established criteria. Accuracy of scale, clarity of units, and the alignment of data with field conditions play a significant role in maintaining the objectivity of the analysis. With accurate and accountable assessment data, the weighting and ranking process can produce reliable and relevant warehouse location recommendations to support decision-making. The data used in this study are primary data obtained through direct collection in the field at several alternative warehouse locations in the Lampung area. This data was then verified through expert judgment discussions to ensure the consistency, relevance, and feasibility of the information as a basis for the development of a Decision Support System for determining strategic warehouse locations.

Based on the data characteristics in Table 1, which includes the assessment of alternatives with various criteria on different scales and levels of importance, this study chooses to use the method proposed within the framework of a Decision Support System based on MCDM rather than an optimization approach. This is because the main goal of the study is not merely to find the mathematically optimal solution, but to produce warehouse location recommendations that are the most balanced and managerially acceptable. Although the values for each criterion are quantitative, the data represent diverse decision dimensions—such as cost, accessibility, capacity, and distribution potential—that are difficult to reduce to a single objective function without sacrificing the strategic meaning of each criterion. Optimization methods tend to require rigid model formulations, assumptions of parameter stability, and linear relationships between variables, which in the context of warehouse location selection are often unrealistic

due to demand dynamics, infrastructure changes, and operational policies. Therefore, the use of the proposed method allows for a more flexible, transparent, and adaptive evaluation process, while also providing more relevant decision support for decision-makers in determining strategic warehouse locations based on real-world conditions on the ground.

4.3. Calculation of Criteria Weights Using the WENSLO Method

The calculation of criterion weights using the WENSLO method is carried out to determine the relative importance of each criterion objectively and based on data. This stage is crucial in the multi-criteria decision-making process because the weights obtained will directly affect the ranking of alternatives. WENSLO takes into account the strength and variation of criterion data through an envelope and slope approach, enabling it to capture differences in the influence of non-linear criteria. With this approach, the weight calculation not only reflects conceptual preferences but also represents the actual contribution of each criterion in the problem of determining strategic warehouse locations.

The first stage in the WENSLO method is to form a decision matrix by collecting the performance values of all alternatives for each criterion, which serves as the main input for analysis using (1) based on the assessment data in Table 2.

$$X = \begin{bmatrix} x_{11} & x_{12} & x_{13} & x_{14} & x_{15} \\ x_{21} & x_{22} & x_{23} & x_{24} & x_{25} \\ x_{31} & x_{32} & x_{33} & x_{34} & x_{35} \\ x_{41} & x_{42} & x_{43} & x_{44} & x_{45} \\ x_{51} & x_{52} & x_{53} & x_{54} & x_{55} \\ x_{61} & x_{62} & x_{63} & x_{64} & x_{65} \\ x_{71} & x_{72} & x_{73} & x_{74} & x_{75} \\ x_{81} & x_{82} & x_{83} & x_{84} & x_{85} \\ x_{91} & x_{92} & x_{93} & x_{94} & x_{95} \\ x_{101} & x_{102} & x_{103} & x_{104} & x_{105} \\ x_{111} & x_{112} & x_{113} & x_{114} & x_{115} \end{bmatrix} \rightarrow \begin{bmatrix} 420 & 82 & 80 & 38 & 18 \\ 450 & 88 & 83 & 41 & 22 \\ 390 & 76 & 78 & 35 & 12 \\ 380 & 85 & 88 & 46 & 30 \\ 360 & 70 & 72 & 37 & 10 \\ 440 & 80 & 85 & 40 & 25 \\ 400 & 78 & 77 & 39 & 20 \\ 495 & 90 & 89 & 50 & 45 \\ 370 & 74 & 73 & 36 & 15 \\ 455 & 84 & 81 & 42 & 28 \\ 410 & 79 & 76 & 38 & 18 \end{bmatrix} \tag{13}$$

The second stage in the WENSLO method is data normalization, which is carried out to convert the criterion values into a comparable scale without changing their relative patterns. Normalization is calculated using (15).

$$\begin{aligned} z_{11} &= \frac{x_{11}}{x_{11} + x_{21} + x_{31} + x_{41} + x_{51} + x_{61} + x_{71} + x_{81} + x_{91} + x_{101} + x_{111}} \\ &= \frac{420}{420 + 450 + 390 + 480 + 360 + 440 + 400 + 495 + 370 + 455 + 410} \\ &= \frac{420}{4670} = 0.0899 \end{aligned} \tag{14}$$

Table 3 presents the results of the overall normalization calculation using the WENSLO method for all criteria and alternatives used in this study as a basis for the weighting process and further analysis.

The third stage in the WENSLO method is the calculation of class intervals, which is done to group the criteria based on the level of influence systematically and objectively. The class intervals are calculated using (3).

$$\Delta Z_1 = \frac{max_1\, z_{ij} - min_1\, z_{ij}}{1 + 3.322 \times log(11)} = \frac{0.1060 - 0.0771}{1 + 3.322 \times 1.0414} = \frac{0.0289}{4.4595} = 0.0065 \tag{15}$$

Table 4 shows the overall calculation results of class intervals in the WENSLO method used to group criteria based on the strength of their influence in the weighting process.

Table 3: Normalization calculation results using the WENSLO method.

Alternative Location	Criteria Code				
	WL-1	WL-2	WL-3	WL-4	WL-5
Location AS	0.0899	0.0926	0.0907	0.0860	0.0741
Location ED	0.0964	0.0993	0.0941	0.0928	0.0905
Location RD	0.0835	0.0858	0.0884	0.0792	0.0494
Location YA	0.1028	0.0959	0.0998	0.1041	0.1235
Location TR	0.0771	0.0790	0.0816	0.0837	0.0412
Location FT	0.0942	0.0903	0.0964	0.0905	0.1029
Location GQ	0.0857	0.0880	0.0873	0.0882	0.0823
Location CT	0.1060	0.1016	0.1009	0.1131	0.1852
Location HO	0.0792	0.0835	0.0828	0.0814	0.0617
Location GK	0.0974	0.0948	0.0918	0.0950	0.1152
Location TU	0.0878	0.0892	0.0862	0.0860	0.0741

Table 4: Interval class calculation results using the WENSLO method.

Criteria Code				
WL-1	WL-2	WL-3	WL-4	WL-5
0.0065	0.0051	0.0043	0.0076	0.0323

The fourth stage in the WENSLO method is calculating the slope analysis, which is carried out to measure the rate of change in each criterion based on the characteristics of its envelope. The slope analysis is calculated using (4).

$$\begin{aligned}\varphi_1 &= \frac{z_{11}+z_{21}+z_{31}+z_{41}+z_{51}+z_{61}+z_{71}+z_{81}+z_{91}+z_{101}+z_{111}}{(11-1)\times \Delta Z_1} \\ &= \frac{1.0000}{0.0065} = 15.4266\end{aligned} \tag{16}$$

Table 5 presents the overall results of the slope analysis calculation using the WENSLO method, which illustrates the sensitivity levels and the strength of influence of each criterion in the weighting process.

Table 5: Slope analysis calculation results using the WENSLO method.

Criteria Code				
WL-1	WL-2	WL-3	WL-4	WL-5
15.4266	19.7556	23.1370	13.1407	3.0962

The fifth stage in the WENSLO method is calculating the envelope value of each criterion, which is determined to represent the upper and lower limits of the normalized data. The envelope value of each criterion is calculated using (5).

$$\begin{aligned} E_1 &= \left(\sqrt{(z_{21}-z_{11})^2+\Delta Z_1^2}\right)+\left(\sqrt{(z_{31}-z_{21})^2+\Delta Z_1^2}\right)+\left(\sqrt{(z_{41}-z_{31})^2+\Delta Z_1^2}\right) \\ &\quad +\left(\sqrt{(z_{51}-z_{41})^2+\Delta Z_1^2}\right)+\left(\sqrt{(z_{61}-z_{51})^2+\Delta Z_1^2}\right)+\left(\sqrt{(z_{71}-z_{61})^2+\Delta Z_1^2}\right) \\ &\quad +\left(\sqrt{(z_{81}-z_{71})^2+\Delta Z_1^2}\right)+\left(\sqrt{(z_{91}-z_{81})^2+\Delta Z_1^2}\right)+\left(\sqrt{(z_{101}-z_{91})^2+\Delta Z_1^2}\right) \\ &\quad +\left(\sqrt{(z_{111}-z_{101})^2+\Delta Z_1^2}\right) \\ &= (0.0091)+(0.0144)+(0.0203)+(0.0265)+(0.0183)+(0.0107)+(0.0214) \\ &\quad +(0.0275)+(0.0193)+(0.0116) \\ &= 0.1792 \end{aligned} \tag{17}$$

Table 6 presents the results of the envelope value calculations for each criterion overall using the WENSLO method as a basis for representing the distribution and relative strength of the criteria in the weighting process.

Table 6: Envelope value calculation results using the WENSLO method.

Criteria Code				
WL-1	**WL-2**	**WL-3**	**WL-4**	**WL-5**
0.1792	0.1230	0.1189	0.1776	0.7160

The sixth step in the WENSLO method is to calculate the proportion value of the criteria envelope to measure the relative strength of each criterion based on the distribution of normalized data, calculated using (6).

$$q_1 = \frac{E_1}{\varphi_1} = \frac{0.1792}{15.4266} = 0.0116 \tag{18}$$

Table 7 presents the calculation results of the proportion values for each criterion overall using the WENSLO method, reflecting the relative contribution of each criterion to the total weight produced.

Table 7: Proportion value calculation results using the WENSLO method.

Criteria Code				
WL-1	**WL-2**	**WL-3**	**WL-4**	**WL-5**
0.0116	0.0062	0.0051	0.0135	0.2313

The seventh step in the WENSLO method is to calculate the value, both calculated and normalized, by integrating the results of the envelope and slope into a single weight value, calculated using (7).

$$w_1 = \frac{q_1}{q_1+q_2+q_3+q_4+q_5} = \frac{0.0116}{0.2678} = 0.0434 \tag{19}$$

Table 8 presents the results of the overall criteria weight calculations using the WENSLO method, which illustrates the relative importance of each criterion in the decision-making process.

Table 8: Criteria weighting calculation results using the WENSLO method.

Criteria Code				
WL-1	**WL-2**	**WL-3**	**WL-4**	**WL-5**
0.0434	0.0233	0.0192	0.0505	0.8637

The final criterion weights obtained through the WENSLO method show the distribution of the importance levels of the criteria formed objectively based on data strength and variation. These weights reflect the relative role of each criterion in influencing the decision on determining the location of a strategic warehouse.

4.4. Calculation of Alternative Values Using the RAWEC Method

The calculation of alternative values using the RAWEC method is carried out to determine the preference level of each warehouse location based on weighted multi-criteria performance. At this stage, the normalized values of each alternative are combined with the criteria weights obtained from the WENSLO method, so that the contribution of each criterion is proportionally reflected in the calculation. The RAWEC process calculates the deviation of alternative values from the criteria weights to represent the suitability of alternative performance in relation to the established importance of the criteria. All these deviation values are then accumulated to produce a final comprehensive alternative value that is easy to compare. With this mechanism, the RAWEC method can produce warehouse location rankings that are consistent, transparent, and rational, serving as a basis for strategic decision-making.

The first stage in the RAWEC method is to form a decision matrix by collecting the performance values of all alternatives for each criterion, which serves as the main input for analysis using (1) based on the assessment data in Table 2.

$$X = \begin{bmatrix} x_{11} & x_{12} & x_{13} & x_{14} & x_{15} \\ x_{21} & x_{22} & x_{23} & x_{24} & x_{25} \\ x_{31} & x_{32} & x_{33} & x_{34} & x_{35} \\ x_{41} & x_{42} & x_{43} & x_{44} & x_{45} \\ x_{51} & x_{52} & x_{53} & x_{54} & x_{55} \\ x_{61} & x_{62} & x_{63} & x_{64} & x_{65} \\ x_{71} & x_{72} & x_{73} & x_{74} & x_{75} \\ x_{81} & x_{82} & x_{83} & x_{84} & x_{85} \\ x_{91} & x_{92} & x_{93} & x_{94} & x_{95} \\ x_{101} & x_{102} & x_{103} & x_{104} & x_{105} \\ x_{111} & x_{112} & x_{113} & x_{114} & x_{115} \end{bmatrix} \rightarrow \begin{bmatrix} 420 & 82 & 80 & 38 & 18 \\ 450 & 88 & 83 & 41 & 22 \\ 390 & 76 & 78 & 35 & 12 \\ 380 & 85 & 88 & 46 & 30 \\ 360 & 70 & 72 & 37 & 10 \\ 440 & 80 & 85 & 40 & 25 \\ 400 & 78 & 77 & 39 & 20 \\ 495 & 90 & 89 & 50 & 45 \\ 370 & 74 & 73 & 36 & 15 \\ 455 & 84 & 81 & 42 & 28 \\ 410 & 79 & 76 & 38 & 18 \end{bmatrix} \tag{20}$$

The second stage of the RAWEC method is normalization, which is carried out to convert the values in the decision matrix into a comparable scale so that they can be fairly compared, calculated using (8) and (9).

$$n_{11} = \frac{x_{11}}{max_1\, x_{ij}} = \frac{420}{495} = 0.8571 \tag{21}$$

$$n_{11'} = \frac{min_1\, x_{ij}}{x_{11}} = \frac{360}{420} = 0.8485 \tag{22}$$

Table 9 and 10 presents the results of the overall normalization calculation using the WENSLO method for all criteria and alternatives used in this study as a basis for the weighting process and further analysis.

The third stage of the RAWEC method calculates the normalized result values combined with the criteria weights to determine the deviation level of each alternative, calculated using (10) and (11).

$$\begin{aligned} v_1 &= (w_1 * (1 - n_{11})) + (w_2 * (1 - n_{12})) + (w_3 * (1 - n_{13})) + (w_4 * (1 - n_{14})) \\ &\quad + (w_5 * (1 - n_{15})) \\ &= (0.0062) + (0.0021) + (0.0019) + (0.0040) + (0.3839) = 0.3980 \end{aligned} \tag{23}$$

$$\begin{aligned} v_{1'} &= (w_1 * (1 - n_{11'})) + (w_2 * (1 - n_{12'})) + (w_3 * (1 - n_{13'})) + (w_4 * (1 - n_{14'})) \\ &\quad + (w_5 * (1 - n_{15'})) \\ &= (0.0066) + (0.0034) + (0.0019) + (0.0121) + (0.5182) = 0.5422 \end{aligned} \tag{24}$$

Table 11 presents the results of the multiplication between the normalized criteria values and the overall criteria weights in the RAWEC method as a basis for evaluating alternatives.

Table 9: Normalization calculation results using the RAWEC method (n_{ij}).

Alternative Location	Criteria Code				
	WL-1	WL-2	WL-3	WL-4	WL-5
AS Location	0.8571	0.9111	0.8989	0.9211	0.5556
ED Location	0.8000	0.9778	0.9326	0.8537	0.4545
RD Location	0.9231	0.8444	0.8764	1.0000	0.8333
YA Location	0.7500	0.9444	0.9888	0.7609	0.3333
TR Location	1.0000	0.7778	0.8090	0.9459	1.0000
FT Location	0.8182	0.8889	0.9551	0.8750	0.4000
GQ Location	0.9000	0.8667	0.8652	0.8974	0.5000
CT Location	0.7273	1.0000	1.0000	0.7000	0.2222
HO Location	0.9730	0.8222	0.8202	0.9722	0.6667
GK Location	0.7912	0.9333	0.9101	0.8333	0.3571
TU Location	0.8780	0.8778	0.8539	0.9211	0.5556

Table 10: Normalization calculation results using the RAWEC method ($n_{(ij)'}$).

Alternative Location	Criteria Code				
	WL-1	WL-2	WL-3	WL-4	WL-5
AS Location	0.8485	0.8537	0.9000	0.7600	0.4000
ED Location	0.9091	0.7955	0.8675	0.8200	0.4889
RD Location	0.7879	0.9211	0.9231	0.7000	0.2667
YA Location	0.9697	0.8235	0.8182	0.9200	0.6667
TR Location	0.7273	1.0000	1.0000	0.7400	0.2222
FT Location	0.8889	0.8750	0.8471	0.8000	0.5556
GQ Location	0.8081	0.8974	0.9351	0.7800	0.4444
CT Location	1.0000	0.7778	0.8090	1.0000	1.0000
HO Location	0.7475	0.9459	0.9863	0.7200	0.3333
GK Location	0.9192	0.8333	0.8889	0.8400	0.6222
TU Location	0.8283	0.8861	0.9474	0.7600	0.4000

Table 11: Weight multiplication calculation results using the RAWEC method.

Alternative Location	Weight Multiplication Result	
	v_i	v_i'
AS Location	0.3980	0.5422
ED Location	0.4890	0.4618
RD Location	0.1533	0.6610
YA Location	0.6002	0.3008
TR Location	0.0116	0.6967
FT Location	0.5358	0.4046
GQ Location	0.4470	0.5029
CT Location	0.6987	0.0088
HO Location	0.2980	0.6024
GK Location	0.5760	0.3439
TU Location	0.3988	0.5414

Table 12: Final score of alternatives calculation results using the RAWEC method.

Alternative Location	Final Value
AS Location	0.1533
ED Location	−0.0286
RD Location	0.6235
YA Location	−0.3322
TR Location	0.9673
FT Location	−0.1395
GQ Location	0.0588
CT Location	−0.9750
HO Location	0.3380
GK Location	−0.2523
TU Location	0.1517

The final stage of the RAWEC method is to calculate the final value by accumulating all the deviations obtained for each criterion calculated using (12).

$$Q_1 = \frac{v_{1'} - v_1}{v_{1'} + v_1} = \frac{0.5422 - 0.3980}{0.5422 + 0.3980} = \frac{0.1442}{0.9403} = 0.1533 \tag{25}$$

Table 12 presents the results of the final value calculations for each alternative overall using the RAWEC method, which is used to determine the final ranking and priority of strategic warehouse locations.

The final scores of the alternatives obtained through the RAWEC method provide a clear picture of the ranking and priority of each warehouse location based on the weighted criteria. These final scores reflect the integration between the performance of each alternative and the relative importance of the criteria, making the resulting rankings objective and proportional. By considering the contribution of each criterion comprehensively, the RAWEC method is able to produce consistent and reliable alternative evaluations. Therefore, these final scores serve as a strong basis for strategic decision-making in determining the most efficient and optimal warehouse location.

4.5. Warehouse Location Analysis and Prioritization

Analysis and prioritization of warehouse locations is an important stage in the Decision Support System, aimed at evaluating the performance of each alternative comprehensively and determining the most optimal priority order. At this stage, the results of the criteria weight calculations from the WENSLO method and the alternative values from the RAWEC method are used to assess the relative advantages of each location based on various aspects, such as cost, accessibility, safety, distribution time, and proximity to suppliers. The analysis process is carried out by comparing the final values of each alternative so that locations that provide maximum efficiency for the supply chain and logistics operations can be identified. In addition, the priorities set also take into account the balance between long-term strategic factors and daily operational factors, so that the decisions made are not only numerically optimal but also relevant to the practical needs of the company. With this approach, decision-makers gain structured and objective guidance in determining warehouse locations that support increased efficiency, cost reduction, and enhanced overall supply chain competitiveness.

Alternative ranking is the final stage in the multi-criteria decision-making process, aimed at determining the priority order of each location based on overall performance against the established criteria. At this stage, the final values of the alternatives obtained from the RAWEC method are analyzed to assess the relative advantages of each location, enabling the most optimal choice to be identified objectively. The ranking process considers the proportional contribution of each criterion, so the resulting ranking reflects a balance between cost, accessibility, safety, distribution time, and proximity to suppliers. In addition to providing clear guidance for decision-makers, alternative ranking also allows for a comprehensive evaluation of risks and operational efficiency, so that the

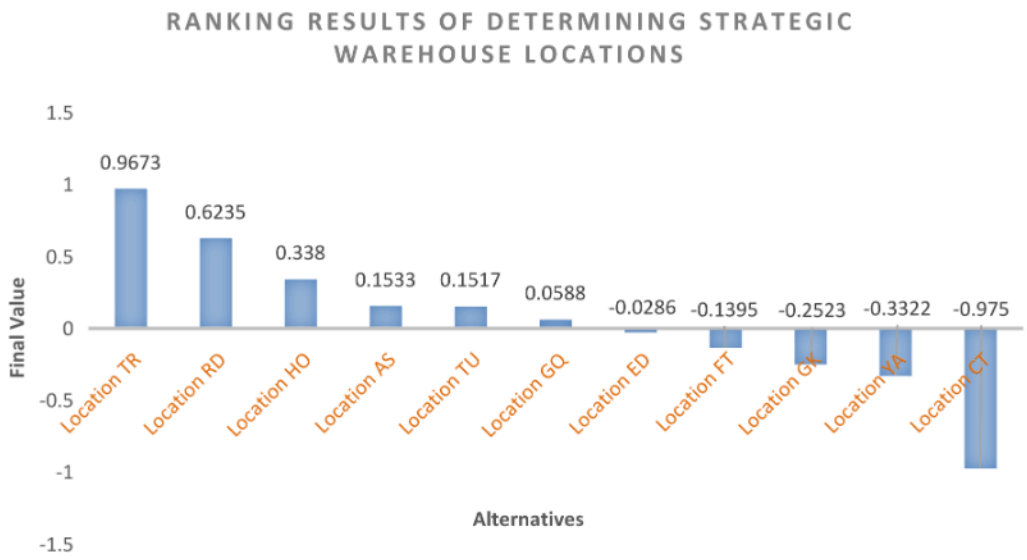

Fig. 2: Ranking results of the determining strategic warehouse locations alternatives.

prioritized locations are not only numerically optimal but also aligned with the company's strategic and practical needs in supporting an effective and sustainable supply chain. Fig. 2 shows the results of the alternative ranking for determining strategic warehouse locations.

The results of the alternative ranking in Fig. 2 show strategic warehouse locations based on the final scores obtained through the RAWEC method. The graph indicates that Location TR ranks the highest with a final score of 0.9673, demonstrating the best performance in meeting all the criteria used. Next, Location RD and Location HO are in second and third place with final scores of 0.6235 and 0.338, respectively, indicating that both perform well but not as optimally as Location TR. On the other hand, some alternatives such as Location YA and Location QC have negative final values, with Location QC being the lowest at −0.975, indicating that the performance of these alternatives is the least in meeting the established criteria. This chart provides a clear picture of the performance differences among the alternatives and makes it easier for decision-makers to determine the priority of the most strategic warehouse locations.

The results of the analysis and prioritization of warehouse locations can be carried out objectively and systematically. TR Location ranks highest with a final score of 0.9673, indicating that this location has the best combination of all criteria, including cost, accessibility, security, distribution time, and proximity to suppliers, making it the top choice for a strategic warehouse. RD Location and HO Location rank second and third with scores of 0.6235 and 0.338, respectively, meaning that both also show fairly good performance, but still fall below TR Location in terms of efficiency and suitability for all criteria. Meanwhile, alternatives such as YA Location and QC Location, which have negative final scores, indicate that these locations are less optimal because their combination of criteria does not support overall logistical and operational efficiency. This analysis emphasizes the importance of considering the ranking of alternatives comprehensively to ensure warehouse location selection is not based on just one or two criteria, but reflects the best performance across all relevant aspects, thereby supporting efficient, reliable, and sustainable strategic decision-making for the company's supply chain.

5. Conclusion

Determining the location of a strategic warehouse is a complex multi-criteria decision problem that requires an approach capable of accommodating differences in the importance levels of criteria as well as variations in performance among alternatives objectively. The integration of the WENSLO weighting method and the RAWEC ranking method has proven effective in developing a systematic and rational Decision Support System, as WENSLO can generate criterion weights that reflect the nonlinear strength of each criterion, while RAWEC can process these weights to evaluate and compare alternatives consistently. The research results show that differences in location

characteristics can be analyzed comprehensively through the stages of normalization, weighting, and calculation of the final value, so that the decisions made do not depend on the subjectivity of the decision-maker, but on data and a clear methodological structure.

The ranking results of the integration of the WENSLO weighting method and the RAWEC ranking method determined TR Location as the most prioritized warehouse location with a final score of 0.9673, indicating the most optimal performance in meeting all the applied criteria. RD Location ranked second with a final score of 0.6235, and HO Location ranked third with a final score of 0.338. Conversely, several alternatives showed less optimal performance with negative final scores, such as YA Location at −0.3323 and QC Location at −0.975, indicating that the characteristics of these locations do not support overall logistics and operational efficiency. This finding confirms that choosing the right warehouse location directly contributes to improved distribution efficiency, reduced logistics costs, and supply chain reliability, while also proving that the integration of the WENSLO and RAWEC methods can produce decisions that are measurable, objective, and scientifically accountable.

This study has several limitations, including the limited number of alternatives and criteria, as well as the use of static data that does not fully represent the dynamics of demand, costs, and risks in the long term. In addition, the approach used has not yet incorporated factors of uncertainty and changes in external conditions such as market fluctuations or supply chain disruptions. Therefore, future research has the potential to develop models by adding more comprehensive criteria, integrating fuzzy or probabilistic-based approaches, and utilizing dynamic or real-time data so that the resulting decision support system becomes more adaptive, accurate, and relevant in various logistics contexts.

CRediT Authorship Contribution Statement

J. Wang: Writing – Review & Editing, Validation, Software, Methodology. **Setiawansyah:** Writing – Review & Editing, Validation, Conceptualization. **T. Ardiansah:** Writing – Original Draft, Methodology. **F. Ulum:** Writing – Original Draft, Data Curation. **Sumanto:** Writing – Review & Editing, Validation, Investigation.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data Availability

The data used to support the findings of this study are available from the corresponding author upon request.

Declaration of Generative AI and AI-assisted Technologies in The Writing Process

The authors used generative AI to improve the writing clarity of this paper. They reviewed and edited the AI-assisted content and take full responsibility for the final publication.

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